Wood Hydronic Heaters – Efficiency and Emissions Testing

Thomas Butcher, Brookhaven National Lab and Nathan Russell, NYSERDA

Abstract

Interest is increasing in the use of wood-fired boilers for meeting space and domestic hot water loads in homes across the Northeast. While the increase use of this local fuel has benefits for regional greenhouse gas emissions there is a concern that these benefits may come at the price of increased emissions of particulates and other pollutants. Combustion technologies and system configurations vary considerably and this is a rapidly emerging area. It is critically important that test methods accurately reflect the performance that these systems are likely to achieve in field operation and that new, low emission technologies be given due credit.

A review was recently completed of the existing method of testing these heaters for efficiency and particulate emissions. The test method, potential sources for improvement and areas where there are accuracy concerns are discussed. This test method has recently undergone a major revision, reflecting, in part, the efforts of this work and the major changes made are also reviewed.

There remain important questions about test loads relative to actual loads in typical homes, performance with large storage volumes (full storage), and smaller storage volumes (partial storage), and fuel charging practices under low load periods which can strongly affect the way that these units operate in the field.

Review of EPA Method 28 Outdoor Wood Hydronic Heater Test Results, Final Report, Sept. 2011. available at www.nyserda.ny.gov

Load profile question: Test method specifies testing at 4 loads, including 15-25% of nominal output. There is a proposal to eliminate the lowest load and test only down to 30% . An analysis of typical building hourly annual heat load profiles was done to evaluate the impact of this on operations and emissions. Most wood boilers are very much oversized and would need to run at very low loads much of the year. The emissions during these periods are very high.

Test Method OWHH 28

- Evaluation of particulate emissions and efficiency of outdoor wood boilers
- Four Load Categories
- Dilution tunnel PM sampling
- Efficiency based on integrated input (wood mass, moisture content, heating value) and output ("Boiler side" water mass flow and temperature rise)
- Many parameters unspecified (return water temperature, measurement time interval)
- Does not include CO

Significant Error Sources

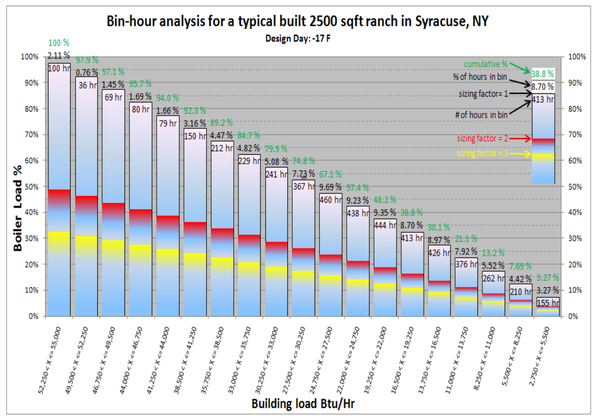
- Low cooling water temperature difference leading to a high error in calculated output energy
- Uncertainty in wood moisture content and heating value

Improved Method 28 – Now in place

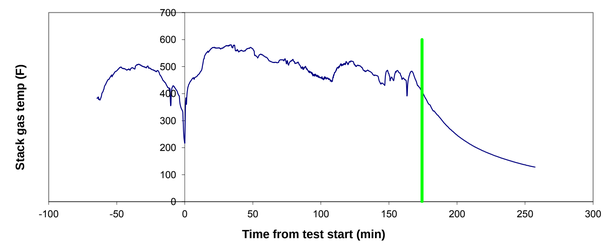
- Output measurement moved to load side, higher temperature difference and accuracy;
- Minimum return water temperature specified
- Improved wood moisture content measurement
- Specified measurement period
- Indoor and outdoor units

Example of Test Results Analysis

			Category				
1 Inputs	symbol	units	I	II	III	IV	Description of measurement
	Ts	F	175	191.3	220.2	377	Average stack gas temperature
	EA	%	117	200	160	66	Excess air
	Tsup	F	166.9	163.5	167.2	153.7	Boiler supply temperature
	Tret	F	164.52	156.1	157.11	133.83	Boiler return temperature
	Tcw	F	83.96	69.17	63.79	57.52	Cold water
	Tcwout	F	158.08	144.45	146.7	131.56	Cooling water out of heat exchanger
	Vfls	gpm	0.277	0.541	0.659	2.199	load side cooling water flow
	Vfss	gpm	4.180	6.850	8.080	8.610	supply side flow rate
	mp	lb/MMBtu	0.29	0.23	0.21	0.05	particulate emissions
	Eff	%	42	78.2	79.4	73	efficiency
	MC	%	19.37	21.13	21.7	21.09	moisture content
	dTload		83.18				
	dTsupply	F	5.2495				
2. Calculations	dTbs	F	5.25	7.40	10.09	19.87	Average boiler side delta T
	MPEbs	%	11.52	8.76	6.96	4.52	Max error in output (boiler side)
	MPEls	%	1.10	1.16	1.10	1.18	Max error in output (load side)
	MPD	%	12.63	9.92	8.06	5.69	Max difference between boiler side and load side output
	APD	%	69.44	21.80	39.50	4.55	Actual difference between boiler side and load side output
	EffComb	%	84.24	81.28	80.84	78.29	Combustion Efficiency
3. Evaluation			5.25	7.40	10.09		High Supply Side Error
							Difference between supply side and load side output out of range
					-1.44		Low combustion efficiency
							Moisture content out of range
						133.83	Low T Return



A typical wood boiler has an output capacity of ~ 150,000 Btu/hr. for a typical home the boiler will run most of the year at much lower output levels.



Stack gas temp profile to illustrate variability during test run. In practice a measurement period of 10 minute was used, contributing to errors.

Particulates increase, in some cases dramatically, as load decreases

M28 OWHH			SR		
	Load	weighting factor		Load	weighting factor
Cat I	<15%	0.437	Cat I	<35%	0.5
Cat II	15-24%	0.238	Cat II	35-53%	0.4
Cat III	25-50%	0.275	Cat III	100%	0.1
Cat IV	100%	0.05			

Future Issues:

- **Capturing accurately the performance of advanced technologies**
- **Evaluating the benefits of storage**

nyserda
Energy. Innovation. Solutions.

BROOKHAVEN NATIONAL LABORATORY